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Bulletin 402

September, 1937

A Study of the Bulb Mite

(*Rhizoglyphus hyacinthi* Banks)

revision Bull. 224
L.B. (G.O.).

PHILIP GARMAN

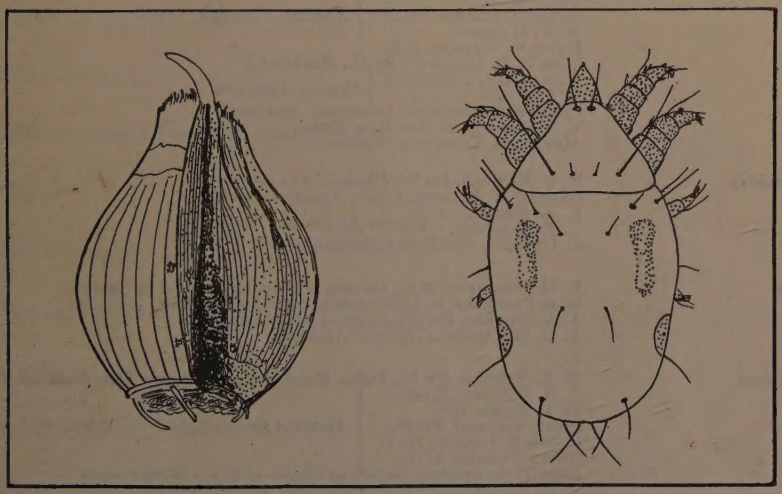

Figure 86. Section of infested bulb, and a mite greatly enlarged.

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Printing by The Peiper Press, Inc., Wallingford, Conn.

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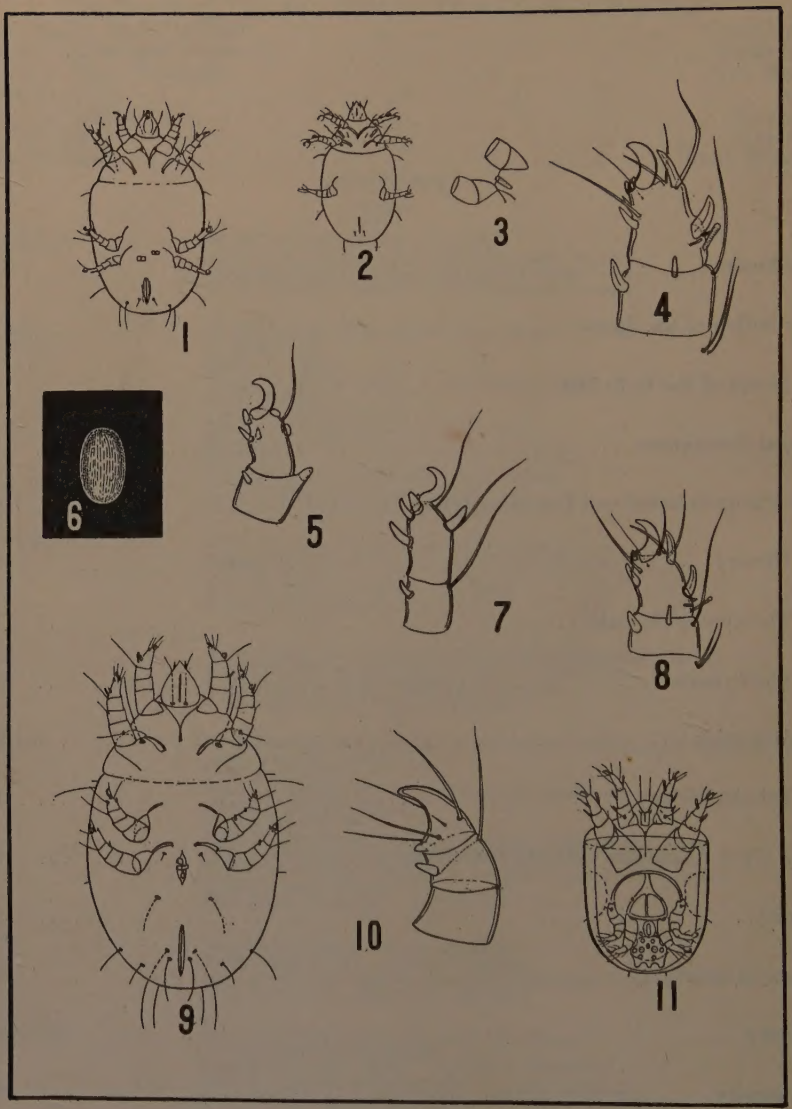

Figure 87. The bulb mite (*Rhizoglyphus hyacinthi* Banks). 1. Protonymph, enlarged about 80 times. 2. Larva, enlarged about 80 times. 3. Larva, sense organ of the ventral surface of the cephalo-thorax. 4. Front tibia and tarsus of the female. 5. Fourth tibia and tarsus of male. 6. Egg, enlarged about 80 times. 7. Fourth tibia and tarsus of the female. 8. Front tibia and tarsus of the male. 9. Tritonymph, enlarged about 80 times. 10. Fourth tibia and tarsus of dimorphic male. 11. Deutonymph or hypopus, enlarged about 80 times.

A STUDY OF THE BULB MITE*

(*Rhizoglyphus hyacinthi* Banks)

PHILIP GARMAN

Inspection of over a million bulbs in Connecticut during 1919 brought to light the significant fact that nearly all shipments contained the bulb mite, *R. hyacinthi* Banks. In many instances only a few infested bulbs were found, but in others as high as 15 to 20 percent were apparently destroyed. Shipments were, however, frequently delayed in transit, according to reports, a state of affairs doubtless responsible for the poor condition of many bulbs when they arrived at their destination. Rotten bulbs, too, are not always the result of mite infestation alone, there being several other causes of rot and disease; but the fact that mites are almost universally found in decayed bulbs has led to the present study of the life history, habits and control of the pest.

Woods (38) claims that the Bermuda lily disease, caused in part by mite infestation, is responsible for a yearly loss of 20 to 60 percent of the entire crop where the plants are forced. Destruction of bulbs has also been noted by many other American and European workers.

Hodson (17, 1928–29) studied the development of the bulb mite under greenhouse conditions and concluded that it is not a primary pest of narcissus, infesting injured or rotting bulbs rather than healthy ones. There are still, however, conflicting views with regard to the importance of the bulb mite, but it is well known that Tyroglyphidae in general are feeders on decaying vegetable matter and fungi of various kinds. It seems probable that the bulb mite is most serious in storage or in semi-tropical countries where breeding conditions are more favorable than in this locality. Ogilvie (25, 1935) concluded that the bulb mite frequently gets a foothold in decayed or injured tissue and may then extend its activity to healthy tissues alongside. The ability to penetrate into the stem of growing Bermuda lilies indicates that it may, under certain conditions, affect the growing plant. The work of Hodson, however, does indicate that healthy plants ordinarily have little to fear from the bulb mite alone. Where mites become abundant in storage, there seems to be agreement that they hasten decay and are, therefore, undesirable. Fortunately, proper storage facilities, as well as treatments for such pests as bulb flies and nematodes or eelworms, destroy the mite satisfactorily or prevent its development.

Some injurious effects of the species in Connecticut were described in the report of the State Entomologist for 1915 (2, Pl. XIV) when 3,000 Easter lilies were destroyed.

DISTRIBUTION OF THE SPECIES

The bulb mite has been reported in shipments to various states and to Canada. Foreign shipments of bulbs to Connecticut come mostly from France, Belgium and Holland, but what is apparently the same species was found in one shipment received from Japan. It has also been reported in bulbs received from the Bermuda Islands and thus seems to have a fairly wide distribution.

* Revision of Conn. Agr. Expt. Sta. Bul. 225.

THE NAME OF THE BULB MITE

Banks (1), in 1906, listed under the name of *Rhizoglyphus hyacinthi* Boisduval a species of mite which he found in bulbs. Since that time Americans have followed the name *hyacinthi* in preference to the name *echinopus* of European authors. Michael (23), however, places *hyacinthi* as a synonym of *echinopus*, with the remark that *hyacinthi* of Boisduval is a *nomum nudum* being listed without description. Michael is correct in this statement, since the original description given by Boisduval is very meager and is not sufficient for purposes of identification. However, the description of *echinopus* given by Fumouze and Robin (10) shows that the latter may also have considered a different species; for the species in hand differs from it (and also Michael's description) in important particulars.

The most striking of these characters are the chitinous thickenings on the fourth pair of legs, which occur both in normal and heteromorphic males. Michael states that the only species bearing this character is *R. crassipes* Haller, which was originally described as an American species (16), but *crassipes* differs in other particulars from our species, and we are forced to conclude that either the chitinous thickenings have been overlooked or the species may be different from all others described. Inasmuch as Michael (l. c., p. 83) says emphatically that "there are not any suckers on the leg of the male of any species except *R. crassipes* Haller" we are able to conclude that he must have examined the species which he described, for this particular character. Examination of material from the U. S. National Museum shows chitinous thickenings on the fourth pair of legs in *R. hyacinthi* and *R. rhizophagus*. The rather frequent presence of the dimorphic male excludes the species in hand from *rhizophagus* and refers it to *hyacinthi*. As already intimated, a search through Boisduval's works has revealed no adequate description of this species and either his name, *hyacinthi*, must be disregarded, or the authority changed from Boisduval to Banks. The latter course is to be preferred and the name *Rhizoglyphus hyacinthi* Banks instead of *Rhizoglyphus hyacinthi* Boisduval should be used, since Boisduval's name cannot be connected with any known species.[1]

For convenience, the description given by Boisduval is quoted herewith. Bank's description of the species is found in Bur. Ent., Tech. Ser. Bul. 13, p. 21, 1906 (pl. V, fig. 49).

Description by Boisduval

Entomologie Horticole p. 86: 1867

"*Nous ne trouvons mentionnè nulle part l'acarus de la Jacinthe; nous ne savons pas s'il n'a pas deja eté observé par quelque naturaliste. Nous lui donnons le nom provisoire d'acarus des Jacinthes Acarus hyacinthi.*"

[1] In spite of the information presented, it is quite possible that the common species in Europe and America are identical. Until proven that the two are the same, the author prefers to retain the name *hyacinthi*. For practical purposes, however, they may be considered the same.

GENERAL DESCRIPTION

Egg (Fig. 87, No. 6): The egg is ellipsoidal, white and semitransparent; .12 by .07 mm. in size.

Larva (Fig. 87, No. 2): Small, white, somewhat ovoid in shape; genital suckers absent. Cephalo-thorax with two long setae on the frontal margin above, and two near the caudo-lateral angle; no minute bristles between the latter as in the adult; venter of the thorax with a clavate sense organ (Fig. 87, No. 3) between the bases of the first and second coxae on each side and small setae mesad of these; front tarsi with strong spines as in the adult, but the clavate hair much longer than the spine immediately beyond it; tip of the tarsus with three slender setae; front tibiae with the usual long setae on the dorsum, the patella (third segment from end beginning with tarsus) each with two shorter setae on the dorsum as in the adult. Abdomen with one pair of legs, the tarsi of each of which bears a long, heavy spine and longer setae on the dorsal surface and three spines on the ventral; tarsal claw very stout; tibiae each bearing a single long seta on the dorsal surface; lateral margins of the abdomen with four setae on each side and a pair near the anal opening.

Size shortly after emergence from the egg, .15-.2 by .1 mm.; full grown, .25 by .15 mm.

Protonymph (Fig. 87, No. 1): Similar to the larva in size and shape but larger and provided with four pairs of legs instead of three; rostrum as in adult; cephalo-thorax as in adult; with two long setae on the frontal margin of the dorsum and two near the caudo-lateral angle; no minute setae between the latter; the front tarsi have, in common with the adult, a minute clavate hair at the base and to one side of the large clavate hair; and between the larger clavate hair and the spine (immediately beyond) is a smaller spine about one-fifth the length of the latter; tip of front tarsi with three slender setae each. The fourth pair of legs has only one seta at the tip of the tarsus and there is no dorsal spine on that segment; however, there is a strong lateral spine and a ventral spine. Judging from the spines and setae on the tarsi of leg three in the larva and the protonymph, the fourth pair of legs of the protonymph must grow in behind the third pair of the larva.

This stage is most easily distinguished from the tritonymph, which it resembles more closely than other stages, by the appearance of the genital suckers. In the protonymph only two make their appearance, while in the tritonymph there are three or four (see Fig. 87, No. 5). There is also some difference in the tarsi of the fourth pair of legs, the latter possessing no dorsal spine in this stage.

Length full grown, about .4 mm.; width about .2 mm.

Deutonymph or **hypopus** (Fig. 87, No. 11): Oval in shape, dorsum convex; venter flat; color brown, the body heavily reinforced throughout with chitin. Rostrum apparently reduced to a small cylindrical projection entirely covered by the cephalo-thorax; distal end of rostrum with two long setae, and a smaller one at the base of each. Mouth parts wanting; cephalo-thorax with two long setae on the front margin placed closely together, and about the same length as the long setae of the rostrum; legs for the most part without the heavy spines of the adult, the latter replaced in most cases by setae; tarsal claws long, curved rather sharply; tarsi of first pair of legs with four slender setae at tip and two near middle of ventral surface. There is also a heavy spine on the ventral surface; a large clavate hair nearly half as long as the segment, and a smaller clavate hair and small seta on caudal surface near the larger one. In front of the larger clavate hair there is also a long seta; front tibia with a long seta on dorsum and a single spine on each side; patella with a single seta at tip instead of two, as in all other stages. Abdomen with conspicuous expulsory vesicles on either side; margin composed of thick, heavy chitin, which shows prominent striations under magnification; venter with conspicuous suckers as in Fig. 87, No. 11, one on each side of the anal opening, two caudad of this, then a row of four, and finally two more. Surrounding the eight caudal suckers is a squarish ring which is thickened at each of its four corners, making it appear as if four additional suckers were present; conspicuous lines of chitin on the venter, extending cephalo-mesad from the anal opening and each coxa of legs III and IV; third and fourth pairs of legs short and usually hidden by the overhanging body wall when viewed from above; tarsi with four setae and two heavy spines at tip; tibiae with a long seta near tip, on dorsum; margin of abdomen with four, minute marginal setae.

Length, .2-.3 mm. Width, .13-.18 mm.

Tritonymph (Fig. 87, No 9): Color white, translucent or semi-opaque, legs brown or tinged with pink.

Rostrum and cephalo-thorax agreeing in nearly all particulars with the adult female. Abdomen as in the adult as regards setae; but the genitalia undeveloped; the genital suckers consist of four indistinct suckers closely approximated (Fig. 87, No. 9).

Length .5-.6 mm., width .3-3.5 mm.

Adult (Fig. 88, Nos. 12-15; Fig. 87, Nos. 4, 5, 7 and 8): Color white, body somewhat transparent; legs, epimera and rostrum brown, sometimes with a pinkish hue.

Rostrum with large mandibles, which are chelate, maxillary palpi with two distinct segments closely joined to the rostrum and a very small projection at the tip, which may represent a third segment. Each of the longer segments with a minute seta, and a longer seta on each maxilla; cephalo-thorax narrowed rapidly in front, the sides gently curved, the front margin with two long setae extending beyond the rostrum and placed closely together; near the caudo-lateral angles of the dorsum are also two long setae between which are two usually minute hairs; venter of cephalo-thorax with conspicuous epimera, the front epimera being united on the mesal line; between the first and second epimera on each side there is usually a small seta; first two pairs of legs thicker than the last two, 5-segmented, the tarsi of the first pair provided with spines and setae as follows: A large clavate sense organ, near the proximal margin on the dorsum, and a large heavy spine just distad of this; a much smaller clavate hair at one side of the larger sense organ, about half its length; between the larger clavate sense organ first mentioned and the spine, distad of it, is a smaller spine about one-third its length; at the tip of the tarsus above there is also a large spine with three setae surrounding it, one of which is much smaller than the rest; ventrad of the tarsal claw there are usually three or four heavy spines, grouped together, and another proximad of these; there is a long seta near the proximal spine and a very inconspicuous one on the opposite surface of the tarsus; tarsal claw not sharply curved; tibia with a long seta on the dorsum near the distal end which is often as long or longer than the tarsal segment; there is a single stout spine on the caudal and ventral surface of this segment; the patella has two closely placed setae near the distal margin of the dorsum and the femur has a single long seta on the ventral surface; the second tarsus is essentially the same as the first, except that the smaller clavate hair or sense organ, and the small spine (between the larger hair and the spine immediately distad) are wanting; one seta is also lacking from the tip; the third and fourth pairs of legs lack the clavate sense organs and are different in the two sexes. In the female and normal male the third pairs of legs are similar; there is a long thick spine at the tip of the tarsus, above and below which is a long slender seta; on the caudal surface of this segment there is also one seta and there is a spine on the opposite surface; the ventral surface has a spine shortly distad of the middle, and a group of about four ventrad of the tarsal claw; the latter is sharply hooked. The third pair of legs of the dimorphic male is much thicker than the third pair of the female or normal male. There are four long setae at the tip, and the tarsal claw seems to be fused with the tarsal segment (Fig. 87, No. 10); the fourth pairs of legs differ in the two sexes but are the same in dimorphic and normal males. In the female there is a distal spine on the tarsal segment just above the claw and one lateral (caudal surface) and one ventral spine in addition, besides a group of three just beneath the claw. There are usually three setae, one above and another below the distal spine, and one lateral seta; in the male the distal dorsal spine is wanting, being replaced by a chitinous thickening sometimes called a sucker; proximad of this is still another thickening and between the two a single seta; the segment possesses the usual number of spines below the claw on lateral and ventral surfaces (Fig. 87, No. 7).

In the female the lateral surfaces of the abdomen are provided with about five setae on each side; the ventral surface with three minute setae on each side of the genital opening and one between the third and fourth coxae, a small one in front of and to one side of the third coxae, and a long one on each side of the anal opening; the genital opening forms an inverted V-shaped figure with two genital suckers on each side (Fig. 88, No. 14); the dorsum has five setae on each side, of which the caudal pair is the longest.

In the male there are the usual five setae on lateral and caudo-lateral surfaces of the abdomen and one minute seta between the third and fourth pairs of legs on the ventral surface, and a smaller one in front of and to one side of the third coxae; genital opening as in Fig. 88, No 12, with two genital suckers on each side. Behind the genital opening are found two larger disc-like suckers, with a minute seta, caudad and cephalad, and usually a row of four longer ones beyond the suckers; setae of the dorsum as in the female.

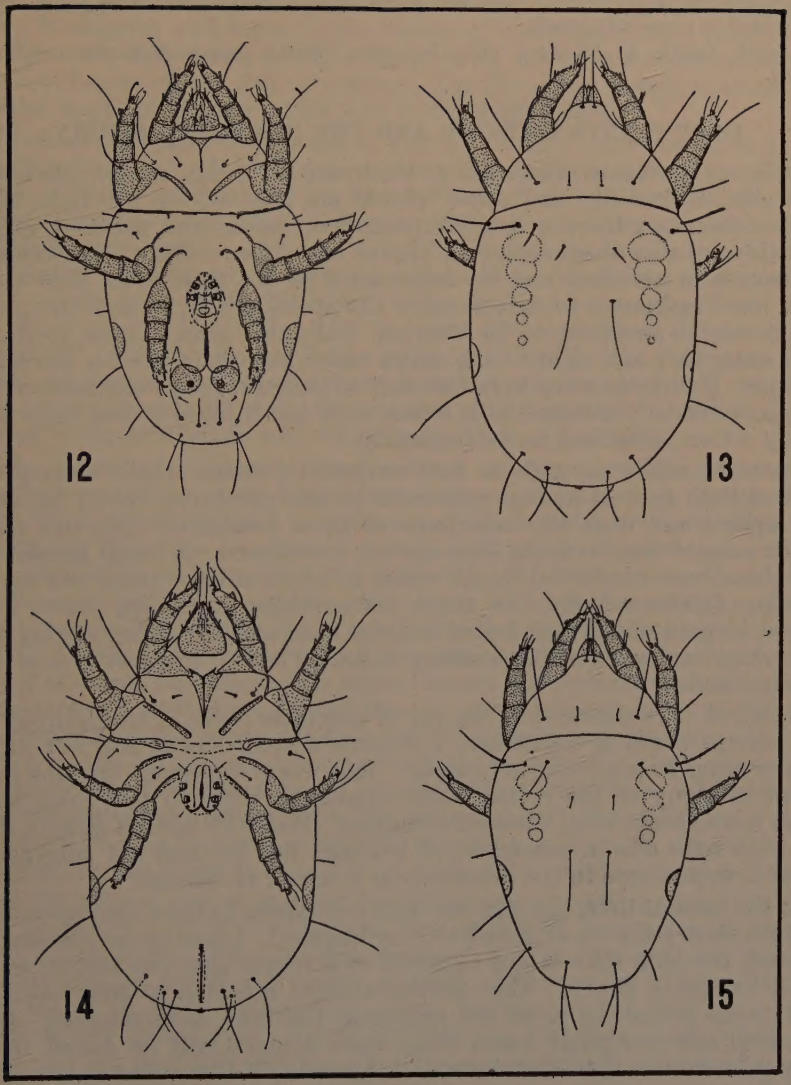

Figure 88. Adult bulb mite (*Rhizoglyphus hyacinthi* Banks), enlarged 80 times. 12. Male, ventral view. 13. Female, dorsal view. 14. Female, ventral view. 15. Male, dorsal view.

Variations: There seems to be some variation both in the length of the setae of the legs and body and also in the thickness of the tarsal segments. Of seventeen individuals, however, measured with the micrometer, the ratio of width to length of tarsus IV ranged from 1-1.6 to 1-2.5, both sexes being examined. There is also a great variation in the depth of the depressions on the dorsum of the adult, they being almost obliterated in some individuals.

Length, female .47-.95 mm.; male .5-.6 mm. Width, female .3-.4 mm.; male .25-.3 mm.

HOST PLANTS INFESTED AND THE RESULTING INJURY

Bulbs of narcissus (Plate II, a, b), hyacinth, tulip, crocus, gladiolus, amaryllis, Easter lily and other plants are infested by the bulb mite. In the laboratory the mite has been reared on onions and potatoes, and is probably capable of subsisting on almost any tuber or bulb. Its common occurrence in narcissus and lily bulbs may be due to the fact that these offer least resistance to attack since the scales are loose and the mites find it easy to penetrate to the interior. Tulips are least injured, owing to their outer skin and tight-fitting scales which leave no place for the mites to enter. Hyacinths seem to be less easy to penetrate than narcissus, while onions, artificially infested with mites, were not injured unless they were partly rotten or bruised in the beginning.

That the mites are able to feed on healthy tissue would seem to be evident both from numerous references to this particular ability by various writers and from the experience of those connected with this office in the case of the Bermuda lilies already mentioned. A small number of tests have been conducted by the writer in which mites entered and fed on growing narcissus bulbs. In these, rotten bulbs containing mites were placed in pots of soil just below healthy ones and the mites readily left the rotten and entered the healthy bulbs. Plate I, b shows one of the infested bulbs.

Welsford (37) claims that the rot of narcissus bulbs is transmitted by the minute worm or nematode, *Tylenchus dipsaci* Kuhn, and not at all by the mite, *Rhizoglyphus echinopus*. This worm, however, has not been found in many of the rotten bulbs examined, while in few cases have mites been absent from diseased examples. Welsford himself admits that the bulb mite does a great deal of damage, but he does not consider it equal in importance to the nematode as a carrier of disease.

At the present time, the eelworm does not appear to have the importance in this country that is attached to it in England. Likewise, as already indicated, the bulb mite is not regarded as a major pest but merely as an agent hastening decay. That narcissus bulbs are able to grow satisfactorily even where the mites are numerous has been demonstrated. It is believed, however, that losses from mite attacks will be found much greater in storage than elsewhere, and injured or rotten bulbs in lots to be stored should be eliminated as a primary means of preventing further loss.

LIFE HISTORY

Few people in America seem to have studied the life history of the bulb mite. Hodson (17) gives a good account of *echinopus* in England, describing the life history at a temperature of 60° F. Yagi (39) published a preliminary note on the life cycle in 1919. In this, he makes known the following facts: "The mite moults twice and the duration of one

generation is about ten days in August, and twenty in June. Temperature is the chief factor in this variation and has an important effect on the embryonic development—the number of eggs laid by one female varied from 9–59, each being dropped singly on the surface of the bulb. The larva is sluggish and bores in the tissues of bulbs and grape vines. The adults mate within two to eight hours after reaching maturity and oviposition begins on the day of mating. The life of the female is about two to four weeks in summer while that of the male is shorter."

Michael (23) reports one case in which he reared *echinopus* from egg to adult in 33 days. He observes three moults instead of two as noted by Yagi. Careful studies by the writer indicate that *hyacinthi* moults three times instead of twice, thus confirming Michael's statement in this regard. When hypopi appear, however, four moults occur instead of three. The life period obtained at room temperature 60 to 75° F. (averaging about 68°) varied from 17 to 27 days; with temperature ranging from 70 to 80° F., 9 to 13 days. The mite becomes torpid at 50 to 55° F. and at about 95°. The air in which the mites lived during the time they were observed was kept as near optimum humidity as possible, which condition was judged largely by daily observance of the amount of moisture contained in the lens paper with which each cell was provided.

The period of incubation (temperature averaging 68° F.) lasts from four to seven days. A six-legged larva emerges from the egg and the mite lives in this condition three to eight days. The last day or so of this period, sometimes two days, is spent in a torpid or quiescent state during which time the larva swells so that the separating line between the thorax and abdomen is lost. On moulting, the larva acquires two additional legs, making eight in all. The next period, which may be known as the protonymph,[1] lasts two to four days, after which follows a second quiescent period of about two days and a second moult takes place. This time there is no increase in the number of legs or much change in form unless a hypopus, or resting stage, is produced. If normal in form, the mite, now known as the tritonymph,[1] again goes into the quiescent state which lasts one to two days, and moults. The adult mite then emerges. If, however, the hypopial state appears after the second moult, the mite may rest for one or two weeks or more, afterwards moulting and giving rise to the tritonymph. The latter then moults and the adult mite emerges as before.

Adults mate a day or so after becoming mature and the eggs are soon laid, beginning with a few daily at first and later increasing in number up to six or eight. Two females observed laid 10 eggs per day for four successive days, but this is rather unusual. The number of eggs laid has been found to vary considerably, some females laying more than 100, others laying only a few. One individual laid 130 eggs in all, while one other laid 81, and still another 59. The males usually die shortly after mating, but if kept separate have been observed at this laboratory to live for more than two months. Females also live from one to two months or more if properly fed and cared for.

The following shows the course of the life history:

Cycle in which hypopial stage is skipped

Egg—larva—first nymph—third nymph—adult female.
Egg—larva—first nymph—third nymph—dimorphic male adult,
normal male adult.

[1] The hypopus is regarded as the deutonymph, and is frequently interpolated between protonymph and tritonymph.

Cycle with hypopial stage

Egg—larva—first nymph—hypopus—third nymph—adult female.
Egg—larva—first nymph—hypopus—third nymph—dimorphic male adult, normal male adult.

The Dimorphic or Heteromorphic Male

The dimorphic male with enlarged third pair of legs (Figure 87, No. 10) has been thought by some to be a distinct species, but it has been definitely proven by others to be merely a form of more or less infrequent occurrence. In one lot of mites examined 36 males were seen without encountering a single dimorphic form. In other lots the males with and without enlarged legs appeared in about equal numbers. The dimorphic males breed freely and the offspring consists of both females and normal and heteromorphic males. One specimen was seen with an enlarged third leg on one side and a leg of normal size on the other. The exact function of the dimorphic male is not clearly understood, nor do we understand the causes which bring about such differences.

The Hypopus

Rather complete studies of the hypopus of *echinopus* have been made by Michael and other European authorities, and it is now regarded as a normal period in the life history of the mite. Briefly explained, it is a form similar to some of its ancestors which is produced from time to time from no apparent reason other than a strong tendency to revert to type and "is a provision of nature for the distribution of the species occurring irrespective of adverse conditions." (22) Hodson (17, p. 190) more recently concludes that slightly unfavorable conditions, except low temperature, may cause development of this stage, but admits a lack of adequate evidence on the subject. Hypopi were more abundant in his cultures during May and September. Notwithstanding, the fact remains that it is often impossible to distinguish between favorable and unfavorable conditions, and it seems certain that conditions promoting their development are not always at hand. The following notes relate to the development of the hypopus.

First of all, it has appeared that hypopi are much more numerous in jars where the bulbs are rotted enough to leave them in a wet, sticky condition. Hypopi are produced in dry as well as moist cells, but more rapidly and frequently more abundantly in the moist cells. This was demonstrated by use of a moisture gradient consisting of four hanging drop slides with small cells, clamped to a larger piece of glass and with a sheet of lens paper between; one end of the gradient being placed in moist sand, and each cell provided with a single pair of mites and the necessary food. The following shows the results of three tests with the gradient described. Cell No. 1 in each case was in contact with moist sand; 2, 3 and 4 farther away in the order mentioned. These tests were then repeated with similar results.

No. of cell	No. of mites	Percent of hypopi	Food used	Date Begun	Date Examined
1	111	27	Unfermented dry narcissus.	May 14	July 7
3	83	7	"	" "	" "
4	90	0	"	" "	" "
			Fermented		
2	39	82	hyacinth.	" "	" "
3	14	50	"	" "	" "
4	105	0	"	" "	" "
			Fresh		
1	213	25	narcissus.	July 24	Sept. 9
2	60	10	"	" "	" "
3	21	0	"	" "	" "
4	60	0	"	" "	" "

On April first a small, tightly corked bottle was provided with about an inch of moist sand and a number of slices of potato previously infested with the bulb mite. These mites did not multiply rapidly but reproduced fairly well, and 100 individuals were counted on June 8, without encountering a single hypopus. Little or no fermentation took place in the bottle until after this date and most of the eggs were laid on the outside of the potato and were fairly dry. However, where the potatoes were in contact with the sand, there was considerable moisture surrounding the developing mites. Only one hypopus was seen in the bottle until July 1. During the latter part of July mold obtained a foothold on the potato but the mites continued to breed, many of them being covered with a wet, sticky film. However, even under such conditions, less than 1 percent of hypopi developed, as was seen by examination on September 9. In order to test the natural ability of the strain on potato to produce hypopi, mites were transferred to glass cells with narcissus or hyacinth at several different periods during the course of the experiment. Hypopi were produced abundantly in practically every case, the percentage varying from 10 to 80 percent. In this bottle and five other similar ones made from it, hypopi did not begin to appear in numbers until about October 25, making a period of some six months when they did not develop. It is difficult to explain the appearance of the hypopus in small cell transfers, but it seems as if some necessary change in conditions must have taken place.

Hypopi developed in light and dark, when fed on decayed and sound food, in moist and dry cells and apparently when warm and cold. They also developed about equally well when the food was covered with small amounts of sugar, alcohol 2 percent and acetic acid 1 percent.

Michael used many experiments to try to induce certain species of Tyroglyphids to develop without producing hypopi, but failed; and he concluded that hypopus is a normal stage in their development. Notwithstanding, in the case of mites like the bulb mite, in which all individuals do not pass through the hypopus stage, it seems hazardous to ascribe such a phenomenon entirely to the inherent atavistic tendency or natural habit of the individuals. It is well known that in a somewhat similar life cycle found in aphids, reversion to the sexual forms which are more commonly skipped are induced largely by changes of weather and food. Some species of aphids, moreover, may be reared continuously without reversion, when proper conditions of moisture, temperature, etc.,

are maintained, and it seems as if something similar must be true of the mites under investigation, caused by factors which we have not yet learned to recognize.

The length of the hypopus stage under favorable conditions is usually a bout one to two weeks.

Migration of the Species

The hypopus is much more active than the remaining stages in the life cycle of the mite, and has a tendency to wander from place to place. It will also attach itself to any moving object. At the time when hypopi become numerous, the bulbs are commonly well rotted and infested by numerous small fly larvae, one of which (*Scatopse pulicaria* Loew) (Plate I, a) was found in large numbers. The flies of this species were frequently found to be literally covered with hypopi attached by means of their ventral suckers. Other hypopi were seen riding peacefully on the backs of predaceous mites, and still others have been found attached to lepidopterous larvae. The mite is thus afforded an admirable means of transportation, of which it is capable of taking full advantage because of its structure and habits.

The tables below show the length of the various stages as determined at this laboratory.

TABULAR LIFE HISTORY OF THE BULB MITE

LENGTH OF EGG STAGE

Length of stage days	Number observed	Dates
		1919
	Temperature 60°-75° F.	
7	8	Sept. 29-Oct. 6.
6½	3	Oct. 10-Oct. 17.
7	4	Oct. 10-Oct. 17.
6½	4	Oct. 10-Oct. 17.
		1920
	Temperature 70°-80° F.	
4	2	July 15-July 19.
3	2	July 16-July 19.
4	3	July 16-July 20.
4	8	July 16-July 20.

LENGTH OF LARVAL STAGE

Length of stage days	Number observed	Dates
		1919
	Temperature 60°-75° F.	
8	1	Oct. 3-Oct. 10.
6	1	Oct. 6-Oct. 11.
7	2	Oct. 6-Oct. 12.
6	2	Oct. 17-Oct. 21.
6	1	Oct. 17-Oct. 22.
6	2	Oct. 17-Oct. 22.
6½	2	Oct. 16-Oct. 21.
		1920
	Temperature 70°-80° F.	
2	2	July 19-July 21.
3	8	July 20-July 23.
3	2	July 18-July 21.
4	1	July 19-July 23.
5	3	July 19-July 24.

LENGTH OF FIRST NYMPHAL STAGE (PROTONYMPH)

Length of stage days	Number observed	Dates
		1919
	Temperature 60°-75° F.	
3	1	Nov. 10-Nov. 13.
3	1	Nov. 12-Nov. 15.
4	1	Nov. 11-Nov. 15.
3	1	Nov. 8-Nov. 11.
4	1	Nov. 8-Nov. 12.
8	1	Nov. 16-Nov. 24.
5	1	Nov. 19-Nov. 24.
3	1	Nov. 20-Nov. 23.
2	1	Nov. 20-Nov. 22.
		1920
	Temperature 70°-80° F.	
2	1	July 21-July 23.
2	1	July 21-July 23.
2	1	July 21-July 23.
1	2	July 21-July 22.
2	2	July 21-July 23.

LENGTH OF HYPOPUS STAGE (DEUTONYMPH)

Length of stage days	Number observed	Dates
		1920
	Temperature 65°-75° F.	
12	1	March 15-March 27.
7	1	March 29-April 5.
5	1	April 17-April 22.
7	1	April 10-April 17.
13	1	April 10-April 23.

LENGTH OF THIRD NYMPHAL STAGE (TRITONYMPH)

Length of stage days	Number observed	Dates
		1919
	Temperature 60°-75° F.	
4	1	Nov. 15-Nov. 19.
3	1	Nov. 11-Nov. 14.
4	1	Nov. 12-Nov. 16.
3	1	Nov. 24-Nov. 27.
3	1	Nov. 23-Nov. 26.
4	1	Nov. 22-Nov. 26.
		1920
	Temperature 70°-80° F.	
3	1	July 23-July 26.
3	1	July 24-July 27.
2	1	July 25-July 27.
3	1	July 24-July 27.
2	1	July 23-July 25.
2	2	July 22-July 24.
2	1	July 23-July 25.

Variations obtained in length of life cycle 9-29 days (with hypopus absent from the cycle); with hypopus included 14-42 days.

OTHER SPECIES OF MITES ASSOCIATED WITH THE BULB MITE

Several predator mites and the Tyroglyphid, *Histiostoma rostro-serratus*, are often associated with the bulb mite. In addition, *Rhizoglyphus rhizophagus* is sometimes found as well as other closely related species. *Histiostoma rostro-serratus* occurs frequently, but seems to flourish in wet, rotten bulbs and has not been observed to feed on healthy tissue. The

small hypopus of this species is produced abundantly and attaches itself to Rhizoglyphus or any moving mite or insect. When observed feeding, the adult Histiostoma is much more granular or opaque in appearance than the bulb mite and often quite light in color. The predator mites commonly encountered belong to the superfamily Parasitoidea, being representatives of the Parasitini or Laelaptini. Hodson identified one of the species occurring in England as *Hypoaspis* sp., but at least four different species have been seen here.

ENEMIES

All the mite predators observed are brown in color and very active when temperatures permit. In one box of bulbs containing about one-fourth bushel, these enemies became very numerous and were seen running about over the bulbs like ants. Doubtless they had destroyed many bulb mites. In another case, a Mason jar containing bulb mites was entirely cleared of them in about a month after the predaceous species was first noticed.

The small Cecidomyid fly, *Lestodiplosis* sp.,[1] was also found feeding upon the bulb mite. The larvae is a small, pinkish maggot which crawls about among the mites and feeds on them. It is about 1 mm. long.

CONTROL MEASURES

Morphological studies show that the mite has no trachael system and cannot be killed, theoretically, by ordinary fumigants. Ewing (7) demonstrated that 4.1 ounces of potassium cyanide per 5,470 cubic feet, or 1 ounce per 133 cubic feet of air space was insufficient to kill the bulb mite. At this laboratory, fumigation with carbon disulfide, 1 ounce to 100 cubic feet, in an air tight container, required 48 hours to obtain a good kill. Mites on the interior of the bulbs were not killed even with this length of exposure. Sorauer (29) recommends for use against the mite, *R. echinopus*, a 48-hour carbon disulfide fumigation or immersion in tobacco extract. Forty percent nicotine sulfate, 1-400, with the addition of soap, killed only 7.1 percent in tests conducted here. Fir tree oil[2] was considerably more efficient, killing 60 to 90 percent in some instances, while in bulbs soaked in water heated to 55° F., nearly 100 percent were killed. Woods (38) treated bulbs with mercuric chloride 1-1,000 and 1-2,000, formalin 1-1,000 and 1-2,000, without success. A good kill, however, was obtained by the writer with formalin heated to 50° C. (122° F.), the bulbs being left for a period of 10 minutes. Nicotine sulfate, 1-400, heated to 50° C., and nicotine oleate heated to 50°, were also very successful acaricides. In all cases, careful observations were made on the hypopus because of its greater resistance, and the mites were examined daily for three days after treatment to be sure of results. Paradichlorobenzene was tried by Ogilvie (25) with some success when used at the rate of 3 grams per cubic foot for 36 hours. He reports that the treatment kills mites in the interior as well as the exterior of the bulbs. Nothing is stated by him regarding action of this material on the bulbs themselves.

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[1] Determined by Dr. E. P. Felt.

[2] No longer available.

Since the above experiments were reported, the hot-water treatment has come into use for bulb pests in general. Milbrath (24, 1925), however, reported that early and late treatments of bulbs even at the recommended (9, 1926) temperatures, 110-111.5°, were sometimes unsatisfactory because of their effect on flowering. Weigel (35, 1928) confirmed Milbrath's experiments and states that hot-water treatment in early August is better than treatments September 1, October 1, or later. He reports further that temperatures above 115° F. reduce the number of flowers in the spikes of paper-white narcissi. It is evident also from the work of Ramsbottom and Van Slogteren that difficulties of a similar nature were encountered in Europe, for Van Slogteren states that the hot-water treatment is not entirely successful on hyacinth (113-115° for 24 hours), and Ramsbottom (26) states that treatment at 110-111° for three hours may be injurious if applied before the flower embryo forms. He considered August and September as safe months for this operation. Van Slogteren (31c, p. 157) stated in 1923 that "the results of the treatment will vary greatly on the time of the treatment and the development of the bulbs." He recognized the effects upon the flowers and stated that much depends "on the way the dry bulbs have been kept *before* and *after* treatment". He maintained that the damage from hot-water treatments can be corrected by holding the bulbs a longer period of time in a "heated bulb house", where development takes place slowly. Apparently realizing the dangers of hot-water sterilization, growers of Wisconsin, as reported by Chambers (4, 1930), were able to sterilize thousands of bulbs without harmful effects. These treatments were made the last week in August and the first week in September.

More recently there has developed an interest in cyanide and carbon disulfide fumigation for various bulb pests. Also, the vapor heat treatment has been revived (18, 1932) and, from experimental evidence thus far presented, appears to be more successful than the hot-water treatment because of less injury to the developing flowers. This method consists of heating the bulbs in a container, using steam instead of hot water and regulating it with a thermostat. Our experience with this treatment indicates that mites are readily killed in all stages with temperatures of 111 to 114° F.

The hot-water treatments described have been tried by us with complete success as far as the mortality of the mites is concerned, and the results of others have been confirmed regarding the periods when injuries to the bulbs are likely to result from the treatments. Short treatments at relatively high temperatures were successful in the original experiments, partly because of the favorable time when the experiments were conducted. The shorter exposures are not recommended for control of nematodes.

Tests with the lower temperatures and longer immersion periods indicate that retardation and injury often result even with lower temperatures if used at unfavorable seasons, or if the bulbs are not handled correctly before or after treatment. In experiments covering this point during 1936 and 1937, all paper-white narcissi heated in January to 110° F. for two and one-half hours, 115° F. for one hour, and 120° F. for one hour failed to bloom, whereas 30 to 60 percent of the bulbs treated in September produced flowers. Conditions in the house after forcing was started were not entirely satisfactory, but there is enough difference in the figures to show the value

of fall treatments. In this connection, Van Slogteren's observations above should be carefully noted. For convenience, the different practises for control of the bulb mite are given below.

Unsuccessful Treatments

1. Hydrocyanic acid gas (HCN), the gas obtained by using 1 ounce potassium cyanide to 133 cubic feet of air space (7).
2. Vacuum fumigation with HCN.
3. Carbon disulfide, 1 ounce to 100 cubic feet—24-hour fumigation.
4. Formalin, 1 part to 1,000 parts water, and 1 part to 2,000 parts water—cold.
5. Nicotine sulfate, 1 part to 400 parts water, plus soap, 2 pounds to 50 gallons—cold.
6. Mercuric chloride, 1 part to 1,000 parts water, and 1 part to 2,000 parts water—cold.
7. Naphthalene fumigation in paper bags at temperatures prevailing in common storage.

Partly or Entirely Successful Treatments

1. Paradichlorobenzene, 3 grams per cubic foot—36-hour treatment.
2. Carbon disulfide, 1 ounce to 100 cubic feet—48-hour treatment.
3. Nicotine sulfate, 1 part to 400, heated to 50° C. (122° F.) for 10 minutes.
4. Formalin (2 percent) heated to 50° C. for 10 minutes.
5. Hot water, 50° C.—bulbs immersed for 10 minutes.
6. Hot water, 43.5° C. (110° F.)—bulbs immersed for 2.5 hours.
7. Vapor heat, 111 to 115° F., averaging 113° F., for 2 hours. (Reported to be effective with 30 minutes to 1 hour exposures.) (18, 30)

Practises of Value in Getting Rid of the Mites

1. Proper care and fertilization of growing plants (see 13, 15).
2. Care in handling after the bulbs are dug in order to prevent bruises, broken scales, etc.
3. Selection of bulbs to be planted or stored, all soft and rotten bulbs to be discarded.
4. Cold storage, 33 to 35° F., to prevent multiplication of mites while stored.

SUMMARY

(1) The bulb mite may injure growing bulbs under some conditions. Ordinarily it is not a serious pest of narcissus.

(2) The life cycle may be completed in less than a month (9 to 29 days) or may be extended to a month and a half if adverse conditions prevail.

(3) It is spread from place to place chiefly by means of the hypopus, which clings to small flies emerging from the decayed bulbs.

(4) Methods commonly employed for controlling mites consist of hot water immersions at 110 to 111.5° F. for two and a half to three hours. Difficulties lie in the selection of the proper time for treatment, and in handling the bulbs correctly before and after. A promising alternative consists of vapor heat treatment with controlled temperatures. The temperatures may apparently be somewhat higher than those used in the hot water method, without injurious effects. Short exposures at a fairly high temperature employing water, or water with nicotine sulfate, have proven successful insofar as controlling bulb mites is concerned.

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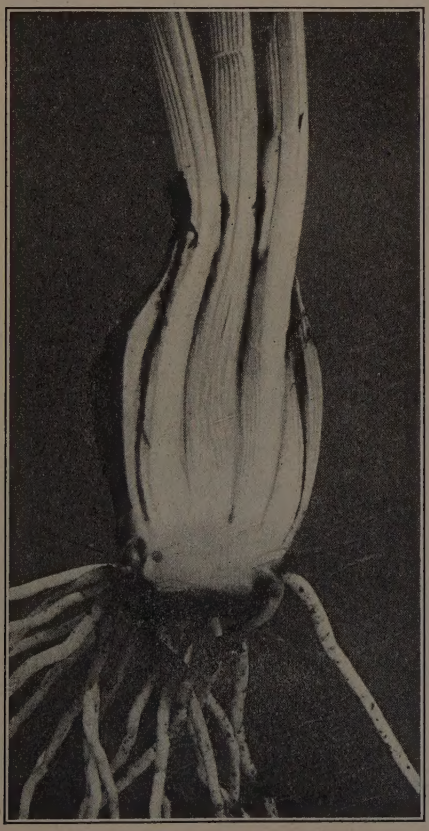
a. Flies, (*Scatopse pulicaria* Loew) with hypopi of the bulb mite clinging to them, enlarged 7 times.

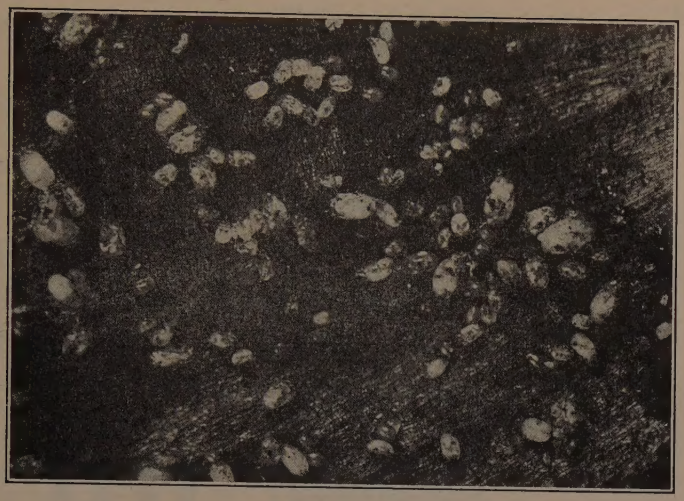


b. Mite infestation just beginning in a growing bulb. Its progress is indicated by the dark lines between the scales, natural size.

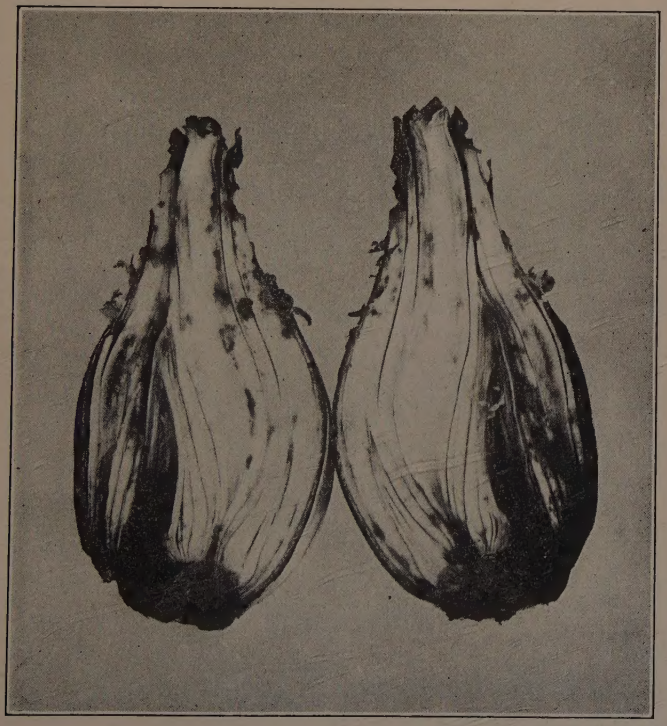
PLATE II.

a. Rotten bulb with base removed showing mites, twice natural size.

b. Bulb completely destroyed and containing a great many mites, natural size.



a. Mites from a rotten bulb, enlarged 8 times.



b. Infestation just beginning in a healthy bulb, natural size.